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Title: LANL Institutional Computing Annual Report Highlight: Local Time-Stepping in Global to Regional Ocean Modeling

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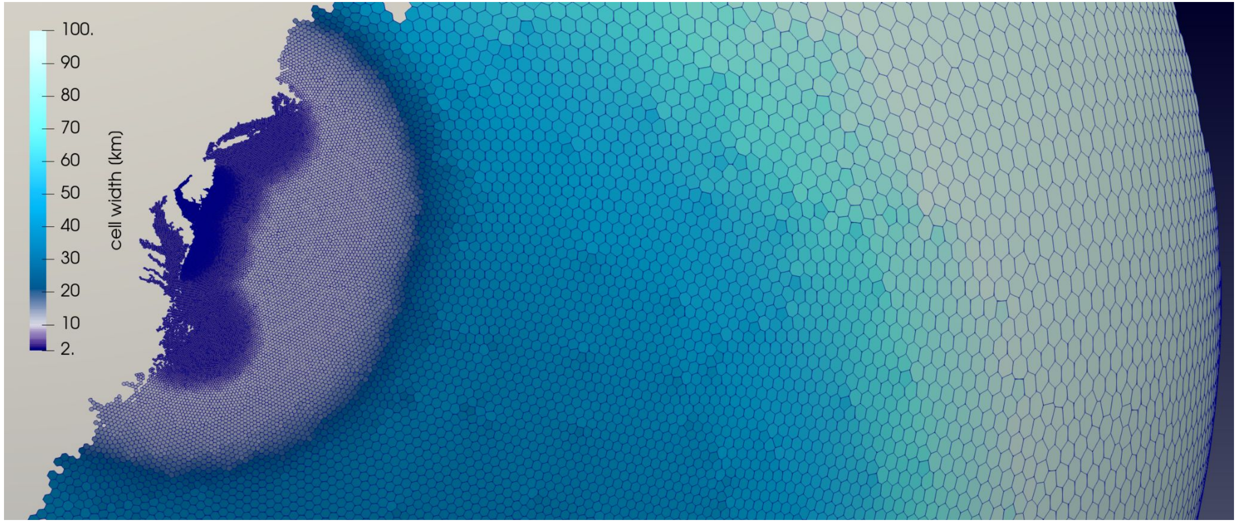
Local Time-Stepping in Global to Regional Ocean Modeling

LANL IC 2020 report, PI: Mark Petersen, Giacomo Capodaglio, CCS-2



Multi-resolution global ocean simulations are possible with the Model for Prediction Across Scales-Ocean (MPAS-Ocean), although the model is currently constrained to a uniform time step. The time step is determined by the size of the smallest cell in the grid, according to the CFL condition. To overcome this issue, a local time stepping (LTS) scheme has been designed for MPAS-Ocean. We have made progress on implementing the LTS scheme, as well as quantitative results and performance tests.

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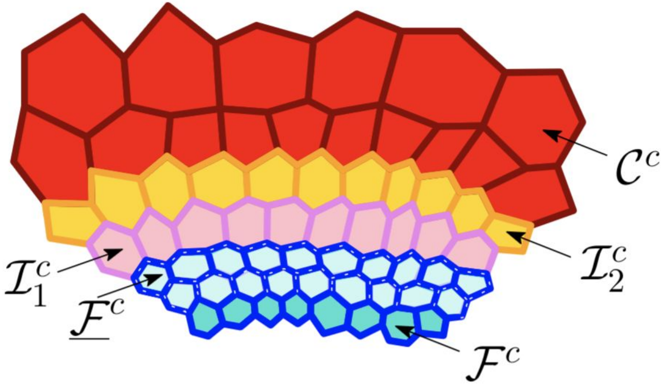

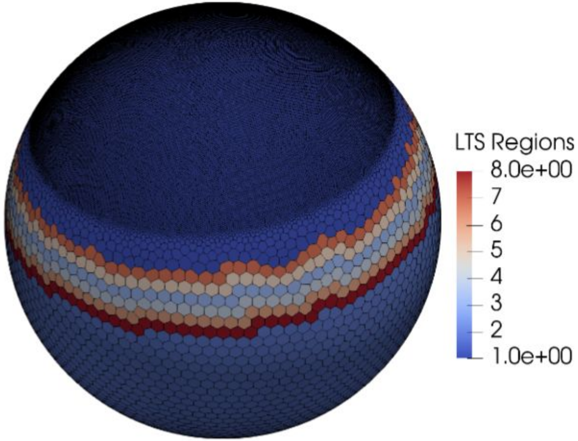

The mesh is divided into regions with fine cells (blue), coarse cells (red) and interface layers (pink, yellow). The time steps subcycle on the fine region according to a positive number M, and conservatively communicate fluxes through the interface. If the coarse time-step is Δt, then the fine time-step is Δt/M. If M=1, no subcycling is done and the same time-step is used on all regions.

The algorithm has been implemented on global variable-resolution meshes with the shallow water equation set, which is a simple single-layer ocean model.

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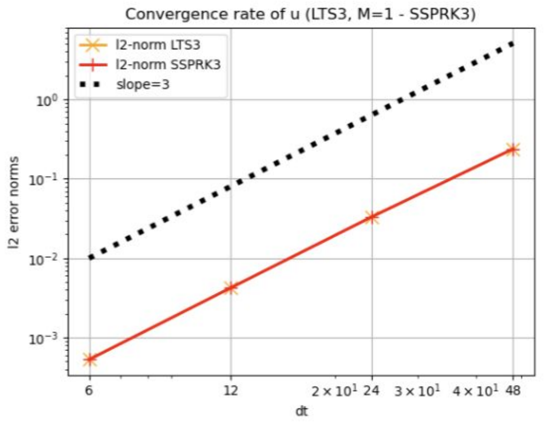
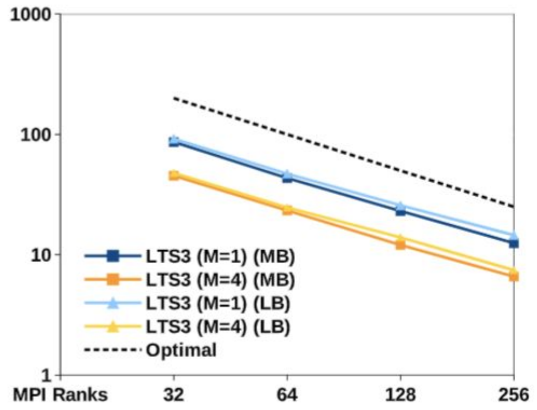


Standard test cases with numerical reference solutions obtained with a Runge-Kutta scheme of order 4 are used to test accuracy and performance. Top plot shows convergence at third order, as expected, for the third order Local Time-Stepping scheme (LTS, yellow) with M=1, which matches up to machine precision the results obtained with the Strong Stability Preserving Runge-Kutta scheme on which it is based (red).



Performance curve comparison between a simulation with a uniform time step (M=1, blue and aqua) and a simulation where the fine region uses four sub-cycled time steps (M=4, orange and yellow). MB refers to a balancing only dictated by the cell sizes whereas LB assigns to each processor a balanced amount of fine, coarse and interface cells. Further improvement of the balancing procedure is under way.